Appendix B
Parcel B Risk Assessment Discussion and Calculations

PARCEL B RISK ASSESSMENT DISCUSSION AND CALCULATIONS

Additional risk assessment calculations were performed to supplement the initial post-demolition risk assessment previously submitted to the RWQCB and HERD (Integrated 1998b) to evaluate potential the human health risks associated with the various deep soil residual impacts in Parcel B. Human health risks were evaluated for the following additional potential exposure pathways using deep soil investigation results:

— inhalation of VOCs in indoor air from upward VOC vapor migration from groundwater into onsite buildings

— inhalation of VOCs in indoor air due to VOC migration from deep soil leachate migration to groundwater and subsequent VOC vapor migration from groundwater into indoor air

Potential further degradation of groundwater due to chemical leaching from soil to groundwater was also evaluated.

The results of the groundwater quality impact assessment are presented below, followed by the results of the additional human health risk assessment.

GROUNDWATER QUALITY IMPACT ASSESSMENT

The objective of the groundwater quality impact assessment is to evaluate whether existing chemical concentrations in deep soils of Parcel B have the potential to degrade existing groundwater quality. Even though shallow groundwater beneath and in proximity to Parcel B is not used as a domestic water supply, the RWQCB requested, as a conservative measure, that an evaluation be conducted of potential downward chemical migration from soil resulting in possible degradation of the Bellflower aquitard. The Bellflower aquitard is the most shallow water-bearing zone beneath Parcel B. This evaluation conservatively and unrealistically assumes that the Bellflower aquitard is a part of the underlying aquifers providing domestic water supply. As described below, the assessment was conducted by further assuming a conservative scenario regarding chemical migration and mixing in groundwater following approved EPA and RWQCB methodology and assumptions.

The maximum COPC concentrations in soil were compared to site-specific soil screening levels (SSLs) derived from California drinking water standards, specifically primary or secondary MCLs. Initial site-specific SSLs were derived using the following formula presented in Section 2.5 of the EPA document entitled *Soil Screening Guidance: Technical Background Document (TBD)*, dated July 1996:

$$\text{Initial SSL} = \text{MCL} \left[(K_{oc} * f_{oc}) + ((O_w + O_a * H')/P_b) \right] \qquad \text{(Equation 1)}$$

Where:

Initial SSL = soil screening level, mg/kg;
MCL = maximum contaminant level, mg/L;
K_{oc} = soil organic carbon-water partition coefficient, L/kg;
f_{oc} = organic carbon content of soil, kg/kg;
O_w = water-filled soil porosity, L_{water}/L_{soil};
O_a = air-filled soil porosity, L_{air}/L_{soil};
H' = Henry's law constant, dimensionless; and
P_b = dry soil bulk density, kg/L.

Site-specific geotechnical parameters are presented in Table B-1. The above equation is a partitioning formula, which does not account for chemical attenuation during migration in soil or mixing with groundwater. To better represent contaminant migration in the soil column, an attenuation factor of 2 was applied to the initial SSLs for VOCs, an attenuation factor of 296 for was applied to the initial SSL for bis(2-ethylhexyl)phthalate, and attenuation factor of 39 was applied to the initial SSL for arsenic. The attenuation factor for VOCs was derived using Table 5-14: Average Attenuation Factor for Different Distance above Ground Water and Lithology presented in the RWQCB's May 1996 *Interim Site Assessment & Cleanup Guidebook* (the Guidebook), and the attenuation factors for bis(2-ethylhexyl)phthalate and arsenic were derived using the formulas presented in Appendix A of that same document. These attenuation factors were derived assuming site-specific average soil particle size distributions of 51 percent sand, 41 percent silt, and 8 percent clay (Table B-2), and a distance of 15 feet from soil impacts to the groundwater table. This distance is considered to be appropriate because it represents the depth at which the deepest soil samples were collected, and thus the closest distance from collected samples to groundwater. Groundwater at the site is approximately 65 feet bgs, and the deepest soil samples were collected from a depth of approximately 50 feet bgs.

An EPA default dilution attenuation factor (DAF) of 20 was applied to the initial SSL to account for limited groundwater mixing. This EPA default value is presented in the above-referenced July 1996 EPA document, and was used by EPA to develop generic SSLs. The resulting site-specific SSL is equal to the initial SSL (assuming no soil attenuation or groundwater mixing) multiplied by the product of a soil attenuation factor (e.g. 2 for VOCs) and a groundwater mixing factor of 20.

The calculation of site-specific SSLs for COPCs that have promulgated MCLs is presented in Table B-3 and B-4. A comparison of the calculated site-specific SSLs with the maximum COPC concentrations in soil is also presented in Table B-3.

The maximum chemical concentrations in onsite soil do not exceed the site-specific groundwater protection concentrations (i.e., site-specific SSLs), with the exception of TCE. TCE concentrations greater than the SSL were only detected at depths between 40 and 50 feet bgs, along the western boundary of Parcel B, which is adjacent to the ILM site. The presence of TCE in this portion of Parcel B is likely due to known VOC impacted groundwater

migration from the ILM site east of Parcel B. In addition, as indicated below, the estimated maximum groundwater concentration due to leaching of TCE from soil to groundwater is less than the existing TCE concentration in groundwater in the nearest onsite well (DAC-P1). Thus, leaching of TCE from deep soil to groundwater would not result in further degradation of groundwater quality.

INHALATION OF INDOOR AIR – VOC VAPOR MIGRATION FROM GROUNDWATER INTO INDOOR AIR

Human health risk associated with VOC vapor migration from groundwater into onsite buildings and subsequent inhalation of indoor air was calculated for the onsite commercial/industrial worker. These risks were estimated using the County of San Diego Department of Environmental Health (DEH) vapor migration model and the highest VOC concentrations in groundwater obtained from the most recent samples (collected in 2001) from groundwater monitoring wells DAC-P1, TMW-14, TMW-15, WCC-10S, and BL-01 through BL-03. The model results are presented in Appendix C, and a summary of the results is presented in Table B-5.

As shown in Table B-5, both the estimated excess cancer risk and estimated hazard index are orders of magnitude less than the OEHHA-approved acceptable target risk levels of 1.0×10^{-5} and 1.0, respectively. Thus, the existing VOC concentrations in groundwater beneath Parcel B do not pose an indoor air health risk greater than the OEHHA-approved risk levels.

INHALATION OF INDOOR AIR – VOC MIGRATION FROM SOIL LEACHATE MIGRATION TO GROUNDWATER AND SUBSEQUENT VOC VAPOR MIGRATION FROM GROUNDWATER INTO INDOOR AIR

VOCs in soil may leach into groundwater and subsequently volatilize from groundwater and, through upward diffusion, migrate through the soil column into indoor air. The SSL equation (Equation 1) was used to estimate maximum VOC concentrations in pore water by substituting the SSL parameter with maximum onsite soil concentrations in the equation to derive the maximum pore water concentration instead of the MCL:

$$C_{pw} = C_s / [(K_{oc} * f_{oc}) + ((O_w + O_a*H')/P_b)] \qquad \text{(Equation 2)}$$

Where:

C_{pw} = maximum VOC concentration in pore water, mg/L; and
C_s = maximum VOC concentration in soil, mg/kg.

The estimated maximum VOC concentration in groundwater was then derived by applying the soil attenuation factor of 2 and the EPA DAF of 20 to the maximum pore water concentration. The resulting estimated maximum VOC concentrations in groundwater are presented in Table B-6. Human health risk associated with the inhalation of vapors in buildings resulting from

migration of VOC vapors from the estimated maximum VOC concentrations in groundwater were calculated for the onsite commercial/industrial worker using the DEH vapor migration model. The model results are presented in Appendix C, and a summary of the results is presented in Table B-7. As shown in Table B-7, both the calculated excess cancer risk and hazard index are orders of magnitude less than the risk thresholds of 1.0×10^{-5} and 1.0, respectively. Thus, vapor migration from groundwater due to VOC leaching to groundwater does not pose an indoor air health risk greater than the OEHHA-approved risk levels.

In addition, a simple comparison between estimated maximum TCE concentrations in groundwater, due to chemical leaching to groundwater, and measured TCE concentrations in groundwater was conducted to assess whether the existing TCE concentrations in soil may further degrade existing groundwater quality. As shown in Table B-8, the estimated maximum groundwater concentration for TCE is less than the most recently measured TCE concentration in the groundwater sample collected from the monitoring well situated closest to the boring with the greatest onsite deep soil concentration of TCE.

CUMULATIVE HUMAN HEALTH RISKS

As indicated in the previous sections, the following additional potential exposure pathways were evaluated using the deep soil investigation results:

- inhalation of VOCs in indoor air from upward VOC vapor migration from groundwater into onsite buildings

- inhalation of VOCs in indoor air due to VOC migration from deep soil leachate migration to groundwater and subsequent VOC vapor migration from groundwater into indoor air

The risks associated with the above-listed exposure pathways, and the estimated risks to potential onsite receptors as presented in the post-demolition risk assessment are summarized in Table B-9. As shown in Table B-9, adding the estimated risks from the above-listed pathways to the estimated risks to the potential onsite receptors do not result in risks greater than the OEHHA-approved risk levels.

Table B-1. Site-specific Geotechnical Parameters at the BRC Former C-6 Facility

Sample ID	Date Sampled	Depth (feet bgs)	Sieve Analysis (Soil Type)	Dry Bulk Density (kg/L)	Moisture Content (percent by weight)	Total Porosity (fraction by volume)	Air-filled Porosity (fraction by volume)	Water-filled Porosity (fraction by volume)	TOC* (mg/kg)	f_{oc} (fraction by weight)
EIA290176-007 (I-34-50)	1/29/2001	50	Fine sand	1.35	4.4	0.51	0.45	0.06	230	0.0002
EIA29176-015 (D-29-50)	1/29/2001	50	Fine sand	1.36	19.5	0.49	0.22	0.26	560	0.0006
EIA29176-024 (I-25-50)	1/29/2001	50	Silt	1.34	24.3	0.51	0.18	0.32	470	0.0005
Average (depths 50 to 65 feet bgs)				1.35		0.50	0.28	0.22		0.0004

It is assumed that the 50-foot sample is representative
of depths between 50 and 65 feet bgs.

Notes:
The air-filled porosity values were calculated from gravimetric data, not volumetric data.

* f_{oc} = the weight fraction of organic carbon in soil = TOC/1,000,000

G: projects/environmental/boeing/C6/ParcelB/Final/ParcelB-tables 1, 2, 3, 4, 6and 9

Table B-2. Soil Particle Size Distribution at BRC Former C-6 Facility

Sample ID	Date Sampled	Depth (feet bgs)	Sieve Analysis (Soil Type)	Median Grain Size (mm)	Particle Size Distribution, wt. Percent						
					Gravel	Sand Size				Silt	Clay
						Coarse	Medium	Fine	TOTAL		
EIA290176-007 (I-34-50)	1/29/2001	50	Fine sand	0.151	0.00	0.00	0.57	79.33	79.90	17.39	2.71
EIA29176-015 (D-29-50)	1/29/2001	50	Fine sand	0.083	0.00	0.00	3.26	47.93	51.19	39.79	9.01
EIA29176-024 (I-25-50)	1/29/2001	50	Silt	0.027	0.00	0.00	0.04	21.27	21.31	64.99	13.70
Average									**50.80**	**40.72**	**8.47**

Average (depths 50 to 65 feet bgs)

0.51	0.41	0.08

It is assumed that the 50-foot sample is representative
of depths between 50 and 65 feet bgs.

G: projects/environmental/boeing/C6/ParcelB/Final/ParcelB-tables 1, 2, 3, 4, 6and 9

Table B-3. Derivation of Soil Attenuation Factor for VOCs and Comparison of Maximum Soil Concentrations to Site-specific SSLs Calculated at 50 Feet Below Ground Surface

CAS No.	Chemical	MCL (mg/L)	K_{oc} [1,2]	f_{oc} [3]	K_d [2,4]	H' [1]	O_w [3]	O_a [3]	P_b [3]	Max. Residual Soil Concentration (mg/kg)	AF for D=15'	Site-specific SSL (mg/kg) at AF = 1	Site-specific SSL (mg/kg) at AF for D=15'	Site-specific SSL (mg/kg) at AF for D=15' and DAF=20	Max > SSL for at AF_T for D=15' and DAF=20?
7440-38-2	Arsenic	5.00E-02	--	4.00E-04	7.90E+02	--	2.20E-01	2.80E-01	1.35E+00	2.50E+01	39	3.95E+01	1.54E+03	3.07E+04	No
117-81-7	Bis(2-ethylhexyl)phthalate	4.00E-03	--	4.00E-04	7.90E+02	--	2.20E-01	2.80E-01	1.35E+00	4.40E+00	296	3.16E+00	9.36E+02	1.87E+04	No
75-35-4	1,1-Dichloroethene (1,1-DCE)	6.00E-03	6.5E+01	4.00E-04	--	1.1E+00	2.20E-01	2.80E-01	1.35E+00	4.40E-02	2	2.50E-03	5.33E-03	1.07E-01	No
127-18-4	Tetrachloroethene (PCE)	5.00E-03	2.7E+02	4.00E-04	--	7.5E-01	2.20E-01	2.80E-01	1.35E+00	5.00E-03	2	2.13E-03	4.54E-03	9.08E-02	No
108-88-3	Toluene	1.50E-01	1.4E+02	5.19E-04	--	2.7E-01	2.20E-01	2.80E-01	1.35E+00	3.00E-03	2	4.37E-02	9.32E-02	1.86E+00	No
79-01-6	Trichloroethene (TCE)	5.00E-03	9.4E+01	4.00E-04	--	4.2E-01	2.20E-01	2.80E-01	1.35E+00	1.70E-01	2	1.44E-03	3.06E-03	6.13E-02	Yes

An SSL was not derived for chemicals that do not have promulgated primary MCLs. These chemicals were not included in the assessment of potential degradation to groundwater quality.

AF = Average attenuation factor based on site lithology (distance to groundwater = 15 feet, 51% sand, 41% silt, and 8% clay).

na = not available

K_{oc} = soil organic carbon-water partition coefficient (L/kg)

f_{oc} = site-specific organic carbon content of soil (kg/kg)

K_d = soil-water partition coefficient (L/kg), $K_{oc} \times f_{oc}$

H' = dimensionless Henry's law constant

O_w = site-specific average water-filled porosity (by volume)

O_a = site-specific average air-filled porosity (by volume)

P_b = dry soil bulk density (kg/L)

[1] Obtained from EPA Region 9 preliminary remediation goal (PRG) physical-chemical data for volatile organic compounds, November 2000

[2] Obtained from Risk Assessment Information System (RAIS) Toxicity & Chemical-Specific Factors Data Base, http://risk.lsd.ornl.gov/cgi-bin/tox/TOX_select?select=csf

[3] Site-specific average values

[4] Obtained from EPA Soil Screening Guidance: Technical Background Document (TBD), EPA/540/R-95/128, July 1996, http://www.epa.gov/oerrpage/superfund/resources/soil/toc.htm

Table B-4. Derivation of Non-VOC Site-specific AFt Following RWQCB Guidance (Depths 12 to 65 feet bgs)

CAS No.	Chemical	K_{oc} [1,2,4]	f_{oc} [3]	K_d [2,4]	H' [1]	O_w [3]	O_a [3]	P_b [3]	O_l	AF_{max}	Distance to Groundwater (feet)	AF_D	AF_T	AF_T
7440-38-2	Arsenic	--	--	7.9E+02	--	2.20E-01	2.80E-01	1.35E+00	5.00E-01	4849	15	182.45	38.86	39
117-81-7	Bis (2-ethylhexyl)phthalate	1.5E+07	4.0E-04	--	4.2E-06	2.20E-01	2.80E-01	1.35E+00	5.00E-01	37065	15	1390.55	296.19	296

na = not available

An AF_T was not derived for chemicals that do not have promulgated primary MCLs. These chemicals were not included in the assessment of potential further

degradation to groundwater quality.

AFT were calculated assuming that the depth between chemical impacts and groundwater is 15 feet and that the soil within this portion of the soil column is

comprised of 51% sand, 41% silt, and 8% clay.

K_{oc} = soil organic carbon-water partition coefficient (L/kg)

f_{oc} = site-specific organic carbon content of soil (kg/kg)

K_d = soil-water partition coefficient (L/kg), $K_{oc} \times f_{oc}$

H' = dimensionless Henry's law constant

O_w = site-specific average water-filled porosity (by volume)

O_a = site-specific average air-filled porosity (by volume)

Ot = site-specific average total porosity (by volume)

P_b = dry soil bulk density (kg/L)

[1] Obtained from EPA Region 9 preliminary remediation goal (PRG) physical-chemical data for volatile organic compounds, November 2000

[2] Obtained from Risk Assessment Information System (RAIS) Toxicity & Chemical-Specific Factors Data Base, http://risk.lsd.ornl.gov/cgi-bin/tox/TOX_select?select=csf

[3] Site-specific average values

[4] Obtained from EPA Soil Screening Guidance: Technical Background Document (TBD), EPA/540/R-95/128, July 1996, http://www.epa.gov/oerrpage/superfund/resources/soil/toc.htm

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Table B-5
Summary of Risk Associated with VOC Vapor Migration from Groundwater

Chemical	Closest Groundwater Monitoring Well	Most Recent Date Sampled	Groundwater Monitoring Well Concentration (mg/L)	Excess Cancer Risk	Estimated Hazard Index
Benzene	BL-01	July 17, 2001	0.00081	1.4×10^{-10}	0.00000023
Carbon disulfide	DAC-P1	Jan. 18, 2001	0.370	No Slope Factor	0.000052
Carbon tetrachloride	TMW-14	July 18, 2001	0.0015	1.8×10^{-9}	0.0000029
Chloroform	TMW-15	July 19, 2001	0.0051	1.2×10^{-10}	0.00000021
1,1-DCA	BL-01	July 17, 2001	0.00035	2.8×10^{-12}	0.000000010
1,1-DCE	TMW-15	July 19, 2001	0.00058	8.4×10^{-10}	0.00000067
Cis-1,2-DCE	BL-01	July 17, 2001	0.012	No Slope Factor	0.0000036
Ethylbenzene	TMW-15	July 19, 2001	0.00023	No Slope Factor	0.0000000023
Isopropyl-benzene	BL-01	July 17, 2001	0.00032	No Slope Factor	0.0000025
Methylene chloride	BL-01	July 17, 2001	0.006	1.6×10^{-11}	0.00000012
Methyl ethyl ketone	TMW-15	July 19, 2001	0.0056	No Slope Factor	0.00000000091
PCE	BL-03	Jan. 18, 2001	0.025	2.4×10^{-9}	0.000032
Toluene	TMW-15	July 19, 2001	0.017	No Slope Factor	0.0000011
TCE	DAC-P1	Jan. 18, 2001	10	2.8×10^{-7}	0.00045
1,2,4-Trimethyl-benzene	TMW-15	July 19, 2001	0.00043	No Slope Factor	0.0000010
Vinyl chloride	BL-01	July 17, 2001	0.003	8.2×10^{-9}	0.000012
Xylenes	TMW-15	July 19, 2001	0.0014	1.3×10^{-10}	0.0000018
Total				2.9×10^{-7}	0.00056

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Table B-6. Derivation of Estimated Maximum VOC Concentrations in Groundwater at Parcel B Using a Site-specific SSL Equation

CAS No.	Chemical	Max. Residual Soil Concentration (mg/kg)	K_{oc} [1]	f_{oc} [2]	K_d [3]	H' [1]	O_w [2]	O_a [2]	P_b [2]	Pore Water Conc. (mg/L)	Groundwater Conc. (mg/L) = Pore Water Conc. / AF / DAF
75-35-4	1,1-DCE	4.40E-02	6.5E+01	4.00E-04	--	1.1E+00	2.20E-01	2.80E-01	1.35E+00	1.1E-01	2.6E-03
127-18-4	PCE	5.00E-03	2.7E+02	4.00E-04	--	7.5E-01	2.20E-01	2.80E-01	1.35E+00	1.2E-02	2.9E-04
108-88-3	Toluene	3.00E-03	1.4E+02	4.00E-04	--	2.7E-01	2.20E-01	2.80E-01	1.35E+00	1.1E-02	2.7E-04
79-01-6	TCE	1.70E-01	9.4E+01	4.00E-04	--	4.2E-01	2.20E-01	2.80E-01	1.35E+00	5.9E-01	1.5E-02

K_{oc} = soil organic carbon-water partition coefficient (L/kg)

f_{oc} = organic carbon content of soil (kg/kg)

K_d = soil-water partition coefficient (L/kg), K_{oc} x f_{oc}

H' = dimensionless Henry's law constant

O_w = site-specific average water-filled porosity (by volume)

O_a = site-specific average air-filled porosity (by volume)

P_b = dry soil bulk density (kg/L)

[1] Obtained from EPA Region 9 preliminary remediation goal (PRG) physical-chemical data for volatile organic compounds, November 2000

[2] Site-specific average values

[3] Obtained from EPA Soil Screening Guidance: Technical Background Document (TBD), EPA/540/R-95/128, dated July 1996, http://www.epa.gov/oerrpage/superfund/resources/soil/toc.htm

G: projects/environmental/boeing/C6/ParcelB/Final/ParcelB-tables 1, 2, 3, 4, 6and 9

Table B-7

Summary of Risk Associated with VOC Vapor Migration from Groundwater as a Result of Leachate Migrating into Groundwater

Chemical	Estimated Groundwater Concentration (mg/L)	Excess Cancer Risk	Estimated Hazard Index
1,1-DCE	0.0026	3.8×10^{-9}	0.0000030
PCE	0.00029	2.8×10^{-11}	0.00000037
Toluene	0.00027	No Slope Factor	0.000000017
TCE	0.015	4.2×10^{-10}	0.00000068
Total		4.2×10^{-9}	0.0000041

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Table B-8
Comparison of Estimated TCE Concentration in Groundwater to Measured TCE Concentrations in Groundwater

Chemical	Maximum Soil Concen- tration (mg/kg)	Estimated Maximum Potential Groundwater Concentration (mg/L)	Closest Groundwater Monitoring Well	Most Recent Date Sampled	Closest Groundwater Monitoring Well Concentration (mg/L)
TCE	0.17	0.015	DAC-P1	1/18/2001	10

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Table B-9. Summary of Cumulative Risks

	Onsite Construction Worker	Onsite Commercial/Industrial Worker	Onsite DTSC Commercial/Industrial Worker
Hazard Index			
Previously Estimated	0.028	0.000016	0.000016
Vapor Migration from Groundwater	NA	0.00056	0.00056
Vapor Migration from Deep Soil Leachate and Subsequent Volatilization from Groundwater	NA	0.0000041	0.0000041
Total	0.028	0.00058	0.00058
Excess Cancer Risk			
Previously Estimated	1.7E-07	2.8E-11	2.8E-11
Vapor Migration from Groundwater	NA	2.9E-07	2.9E-07
Vapor Migration from Deep Soil Leachate and Subsequent Volatilization from Groundwater	NA	4.2E-09	4.2E-09
Total	1.7E-07	2.9E-07	2.9E-07

NA = Not applicable

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